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6. AUTHOR(S)
Dr. John Anderson
Psychology Department

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Carnegie-Mellon University
Pittsburgh, PA 15213

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The final project was to assess the suitability of eye movements to provide information about the nature of interaction between student and tutor. In this project, we used the PAT algebra tuto that has been used at Carnegie-Mellon University. Here we showed that student eye movements could serve to predict when they were going to make errors and to diambiguate the interpretation of various actions. We also found that they informed us about when students actually processed help messages and error messages presented by the tutor. In his dissertation, Kevin Gluck identified a number of instructional opportunities afforded by eye movements. He also developed an ACT-R model of interaction with the tutor that predicted eye movements.

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Final Progress on AFOSR F49620-95-1-0284

Proposal to Extend and Test Cognitive Tutors

April 1, 1995 – December 31, 1998

John R Anderson
Carnegie Mellon University
Psychology Department
Pittsburgh, Pennsylvania 15213
ja+@cmu.edu

Objectives

The objective of the project was to develop ACT-R models of student use of computer-based instruction. The principal focus of our research was developing a model of student interaction with Valerie Shute's Stat Lady. We wanted to learn information about the appropriateness of ACT-R for this kind of project, evaluate different methodologies, and make suggested improvements to Stat Lady. This effort required collection of detailed subject verbal protocols, development of an ACT-R simulation of student behavior, and validation of that simulation against the large corpus of data collected at the Armstrong Human Resources Laboratory. We then used the cognitive model to suggest variations on the Stat Lady system and assessed these in experiments at Train Laboratory at Lackland Air Force Base. We also investigated how informative eye movement protocols were relative to verbal protocols.

Research Summary

We videotaped and transcribed the interactions of four students working with the descriptive Statistics module of Stat Lady. For two of the sections in this module (Simple Frequency Distributions and Grouped Frequency Distributions) we coded all the interactions and identified all the learning events (where particular curriculum objectives were learned). We validated this detailed data against computer records of 180 students from the TRAIN laboratory at Armstrong. We focused on modeling student interactions in the scenarios within a section because this is where students spend most of their time and this is where most of the effort has gone into the design of Stat Lady. We showed that subjects speed up both because they read less of the instruction and because they speed up in the individual steps of scenario interaction. We developed an ACT-R model that read the instruction and performed the individual steps of the scenarios. It learned to skip those parts of the instruction that are uninformative and memorized other parts of the instruction. For both reasons it was able to model subjects' drop out of reading. It also strengthened its knowledge representation and for this reason came to perform the individual steps more rapidly. It was the first detailed cognitive model of the process of interacting with instructional software. We have subsequently validated this model against a larger population of subjects at the TRAIN laboratory. We also used it to make a set of suggested modifications to Stat Lady which have also been validated in a new at the TRAIN lab.

We developed an ACT-R model of an student which can interact with a LISP-based emulation of Stat Lady. The simulation was able to reproduce the learning of the Stat Lady subjects. It identified much of this learning as interface driven. It also suggested that much of the interaction in Stat Lady does not contribute to learning of curriculum objectives. As such, it suggested that we would produce a much "leaner" version of Stat Lady which would accomplish the same curriculum objectives. We developed an alternate version of Stat Lady that did not involve as elaborate feedback or as rich scenarios. In an assessment at the TRAIN Lab we showed that this version of the tutor was as successful in achieving curriculum objectives, did so in less time, and without sacrificing student measures of enjoyment. This is a demonstration of how a cognitive micro-analysis of a system can lead to the design of a more effective system.

The final project was to assess the suitability of eye movements to provide information about the nature of the interaction between student and tutor. In this project we used the PAT algebra tutor that has been used Carnegie Mellon University. Here we showed that student eye movements could serve to predict when they were going to make errors and to disambiguate the interpretation of various actions. We also found that they informed us about when students actually processed help messages and error messages presented by the tutor. In his dissertation, Gluck identified a number of instructional opportunities afforded by eye movements. He also developed an ACT-R model of interaction with the tutor that predicted eye movements.

Personnel Support over the History of the Grant

1. John Anderson, Principal Investigator
2. Kevin Gluck, Graduate Student
3. Marsha Lovett, Research Scientist
4. Daniel Bothell, Research Programmer
5. Joon Park, Undergraduate Research Assistant
6. Serene Taleb-Agha, Research Programmer

Publications and Manuscripts

Gluck, K. A., Lovett, M. C., & Anderson, J. R. (1997, August). The adaptive nature of learning from Stat Lady. In *Proceedings of the 19th Annual Conference of the Cognitive Science Society*, Stanford, CA.

Gluck, K. A., Lovett, M. C., Anderson, J. R., & Park, J. W. (1997, June). Learning about learning from Stat Lady. In *Proceedings of the World Conference on Educational Multimedia and Hypermedia*, Calgary, Canada.

Lovett, M. C. (1996). Are the new methods better? A cognitive psychologist's view on evaluating methods for teaching Statistics. *In Proceedings of the Section on Statistical Education*, Alexandria, VA: American Statistical Association.

Gluck, K. A., Shute, V. J., Anderson, J. R., & Lovett, M. C. (1998, August). Deconstructing a computer-based tutor: Striving for better learning efficiency in Stat Lady. Paper presented at the 4th International Conference on Intelligent Tutoring Systems, San Antonio, TX.

Gluck, K. A., Shute, V. J., Anderson, J. R., & Lovett, M. C. (1998). The Stat Lady tutor design project: Exploring feature and context manipulations for better learning efficiency. Manuscript in revision.

Gluck, K. A., Lovett, M. C., Anderson, J. R., & Shute, V. J. (1998). The curriculum and the interface: A componential analysis of the learning curve. Manuscript in revision.

Gluck, K. A. (1999). Eye movements and algebra tutoring. Doctoral dissertation. Carnegie Mellon University, Department of Psychology. Pittsburgh, PA.

Interactions/Transitions

We have established contact with Wes Regian and particularly Valerie Shute at Brooks Air Force Base. Valerie Shute visited CMU in May of 1996 and developed plans for collaboration. Kevin Gluck visited the San Antonio labs numerous times. He and Valerie Shute collaborated on the redesign of Stat Lady and its testing in the TRAIN laboratory. He made a presentation of the modeling work on ACT-R at the Fourth Annual ACT-R Workshop and at the ITS 98. Marsha Lovett gave a presentation at the American Statistical Association on evaluation of Statistics instruction.

Honors/Awards

1994 American Psychological Association's Distinguished Scientific Career Award

1999 National Academy of Sciences

1999 Fellow, American Academy of Arts and Sciences